Influence of the barotropic mean flow on the Atlantic Equatorial Deep Jets

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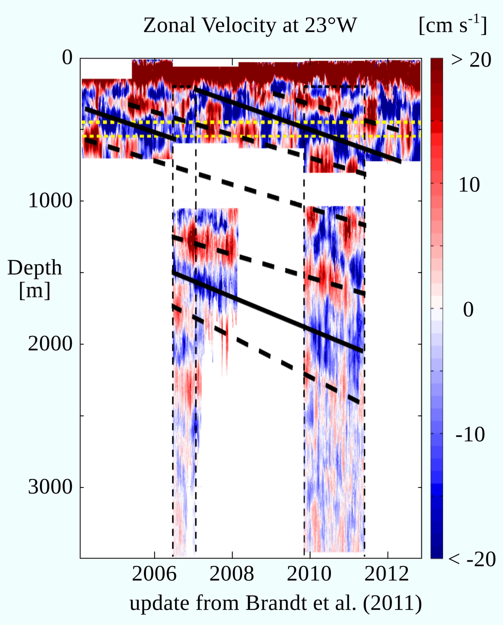
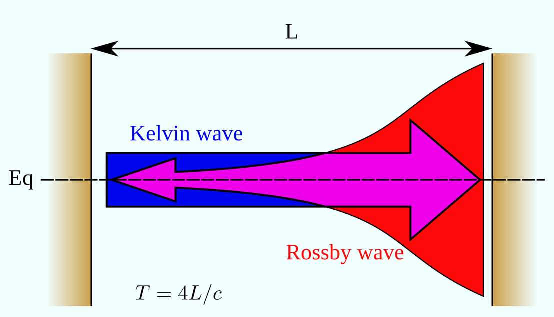
Conclusions

- Eastward flanking jets shield the equatorial wave guide from extratropical Rossby waves
- Westward mean flow along the Equator widens the cross-equatorial structure
- Increasing lateral viscosity predominantly widens the Kelvin wave while the Rossby wave is confined by the flanking jets
- Focussing is not a likely feature of the Atlantic Equatorial Deep Jets

Introduction

The Atlantic Equatorial Deep Jets are geostrophically balanced stacked zonal jets along the Equator:
The horizontal scale is comparable with the basin width; the vertical scale is about 300 - 700 m; they can be found between 200 and 3000 m; the amplitude exceeds 10 cm s^{-1}. The timescale of downward phase propagation is ~4.5 years (Brandt et al. 2011).





The similarity between the Equatorial Deep Jets and the gravest equatorial basin mode (Cane and Moore, 1981) is often noted, e.g., by Johnson and Zhang (2003). However, the width of the Equatorial Deep Jets is about 50% larger than one would expect based on inviscid linear theory and their vertical scale.

Question

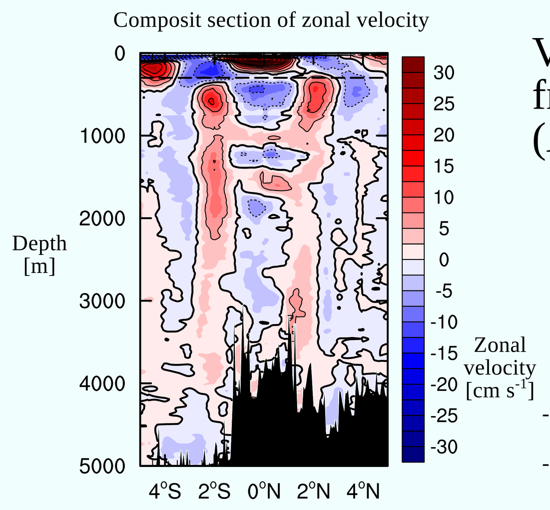
Can the presence of the barotropic mean flow explain the enhanced widening and how does it affect the structure of the equatorial basin mode?

Models

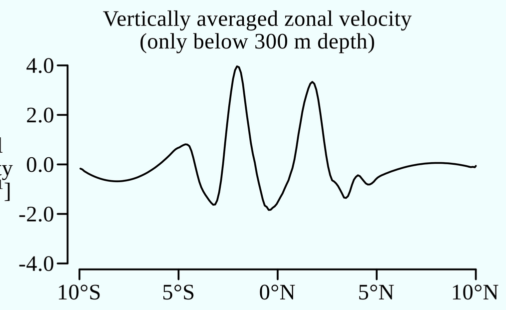
Ray tracing of Rossby waves:
- based on the local dispersion relation $\omega = Uk + Vl - \frac{k\tilde{f}_y - l\tilde{f}_x}{k^2+l^2-R_c^{-2}}$, $\tilde{f} = f + V_x - U_y$
- quasi-geostrophic approximation is made if mean flow is considered

Shallow water model:
- single high order baroclinic mode
- linearised about a barotropic mean flow
- periodic forcing in the zonal momentum equation

Mean flow



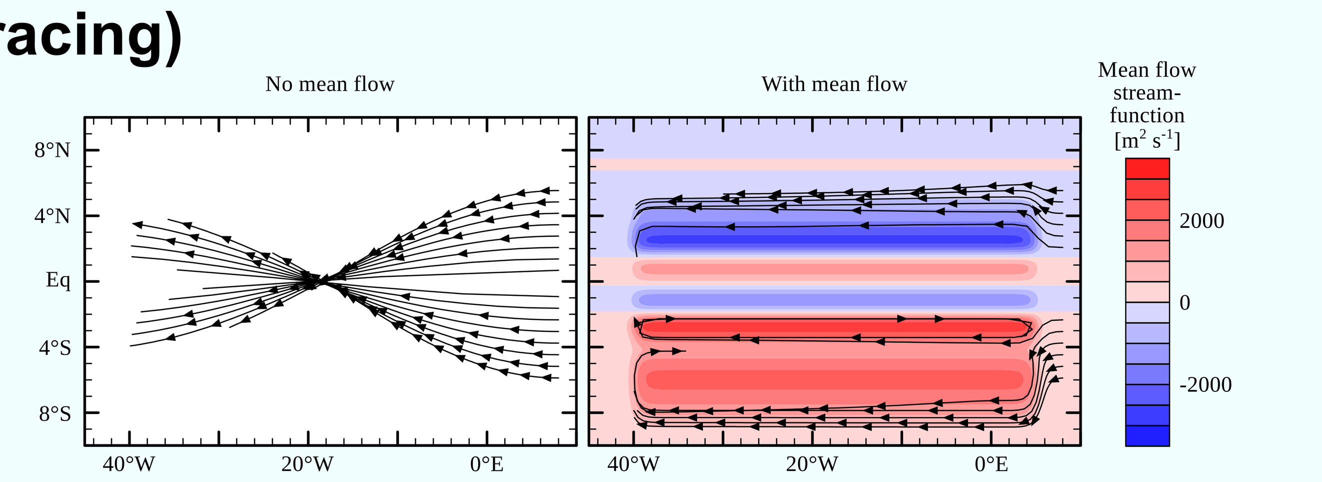
Velocity data are collected from 22 cruises at 23°W (Aug. 1999 - Nov. 2012)



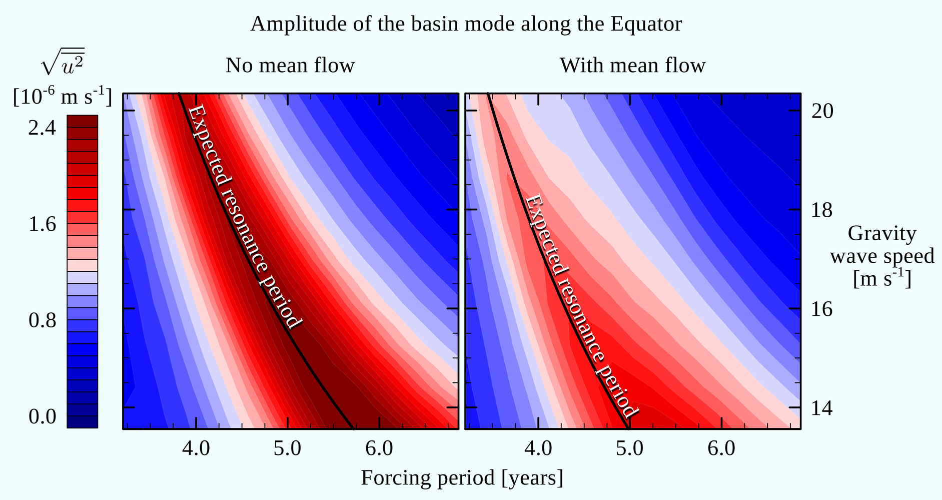
Results

Influence of the mean flow on the inviscid free basin mode (Ray tracing)

Without mean flow, the rays of the free inviscid Rossby waves focus in the centre of the basin due to beta dispersion (Schopf et al. 1981). In the case with mean flow, the Rossby waves' local group velocities are determined by the mean flow. The equatorial wave guide is shielded from extratropical Rossby waves and no focussing is present.



Resonance of a forced, weakly damped basin mode

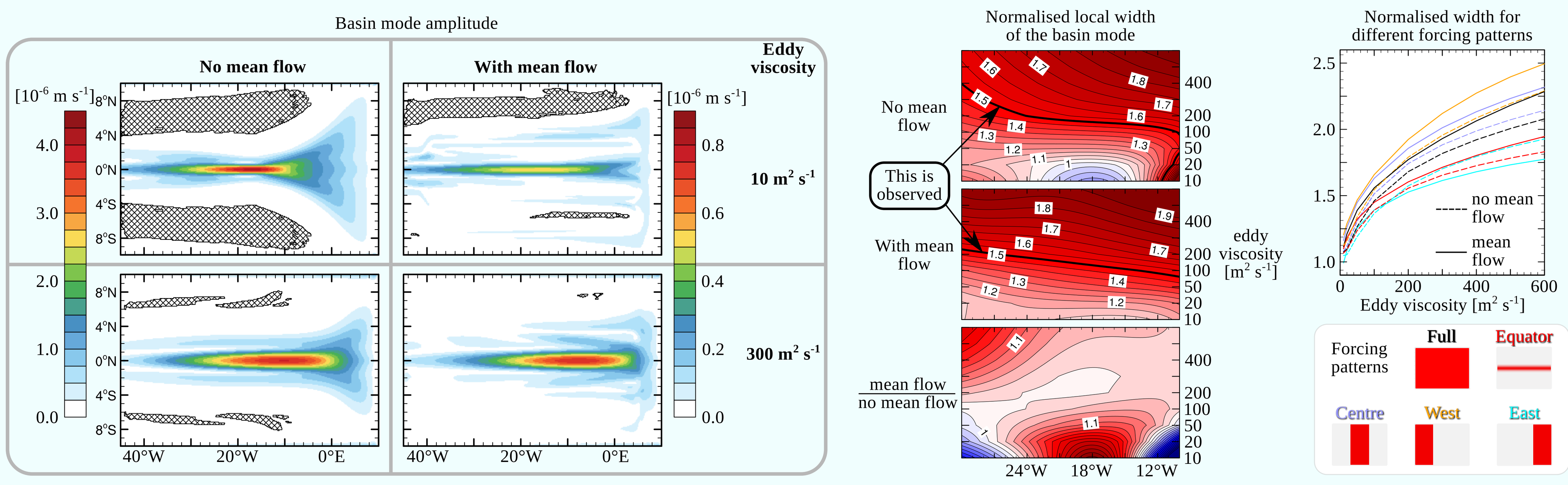


The shallow water model is repeatedly driven by oscillating forcing, which is confined to the Equator. For each run, the amplitude of the basin mode along the Equator is estimated as the root mean square of zonal velocity, when the model is in a steady oscillating state. The expected resonance period is given by

$$T = \int \frac{1}{c+u_{eq}} + \frac{1}{\frac{c}{3}-u_{eq}} \mathrm{d}x$$

and nicely fits the model results. The resonance amplitudes in the presence of the mean flow are reduced by a factor of 24-35% compared to the cases without mean flow. This is further evidence for the shielding of the equatorial wave guide by the mean flow.

Impact of lateral mixing on a forced basin mode



For relatively little mixing applied, the model without a mean flow shows a strong focussing in the centre of the basin which is absent in the run including mean flow. Increasing the lateral mixing lead to remarkably similar results in the vicinity of the Equator for both cases, with and without mean flow. Also the location of maximum amplitude shifts eastward.
The presence of the mean flow generally widens the basin mode. For eddy viscosities below 100 m^2 s^{-1} this is due to the lack of focussing in the centre. Above that threshold the widening is strongest in the western part. The more the forcing is applied to the west, the greater is the widening by the mean flow and the sensitivity to lateral mixing.

References

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Acknowledgments

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What's next

Why does the energy associated with the Equatorial Deep Jets propagate upward?